The Exploratorium exhibits

recreated worldwide for Outdoor Science Parks

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Introduction

India is credited worldwide for creating the first full-fledged outdoor science exposition called 'Children's Science Park' in 1979, during the International Year of the Child, at Nehru Science Centre in Mumbai. A review by the author shows that India has set up 40 science parks between a span of 35 years, from 1979 to 2014. The majority of the exhibits of these parks explain basic principles of physics through interactive or hands-on exhibits.

It is possibly not known to many that the first set of physics based exhibits suitable for outdoor exposition, with visitors as part of the interaction, were created in the United States of America at the Exploratorium in San Francisco in 1977. India too had produced physics playground exhibits, not exactly similar to Exploratorium exhibits, but a year later in 1978 at Nehru Science Centre. This journey had taken a boost and starting from late 1980s, Science Parks outside India have been thriving in all the continents of the world, including USA and they too bank primarily on physics based exhibits.

Frank Oppenheimer and the Exploratorium

The Exploratorium was created by physicist and educator Dr Frank Oppenheimer and his dedicated team of colleagues including scientists, technologists, artists and educators. It was opened at the Palace of Fine Arts in 1969 and remained there until 2 January 2013. The new Exploratorium was opened at Piers 15 and 17 on San Francisco's Embarcadero.

Frank Oppenheimer (1912-1985) was born in New York City. During 1930s, he earned a B.S. degree in Physics from Johns Hopkins University and a PhD from the California Institute of Technology, for his work on artificially induced radiation. He joined the top secret Manhattan Project at Los Alamos in 1945, which was directed by his brother J. Robert Oppenheimer.

1. Dr Frank Oppenheimer

After the World War II, Frank became a professor of physics at the University of Minnesota. But he had to resign from the position in 1949 due to pressure from the House of Un-American Activities Committee. After spending about eight years as a cattle rancher in Pagosa

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Springs in Colorado, Oppenheimer found a job of a school teacher and taught physics, chemistry and biology at Pagosa Springs High School. He then focussed his attention towards science education. Two years later Frank was appointed at the University of Colorado as a professor of physics. There he created a 'library of experiments', to help students to conduct experiments for in-depth study of science subjects. [1]

While still in the University of Colorado, Oppenheimer cherished a keen desire to set up a science museum with hands-on exhibits. A few years later he thus started his dream project at 'The Palace of Fine Arts' in San Francisco with an initial funding of USD 50,000 from the San Francisco Foundation. The palace was originally built in 1915 to hold the 'Panama Pacific Exhibition' to celebrate completion of the Panama Canal. A cavernous hall of approximately 8000 sq. meters floor area (305 m. long, 37 m. wide and 12 m. high) in the palace was considered as an ideal space by Oppenheimer to build his science museum. That began his toil in creating the fantastic museum of interactive exhibits. In order to avoid passive undertone of the word 'museum' he named it 'The Exploratorium'. Most of the exhibits of the Exploratorium were fabricated in-house, some were gifted by industries, government agencies, artists, scientists, students and also by staff members of the centre. The Exploratorium was established in 1969. The Exploratorium's main objective was not to collect and display objects, but to teach principles of science and technology through interactive and hands-on exhibits. Gradually, the number of exhibits grew to nearly 200 pieces by 1972. Since then Exploratorium has created over 1,000 participatory exhibits. [2]

From the very beginning of the Exploratorium, Frank Oppenheimer was keen to share its expertise with science centres and other types of museum. As a result, three Cookbooks were released by Exploratorium that explained in detail the design criteria and working principles of more than two hundred hands-on exhibits. Such books came to Indian science museums from Exploratorium as free gifts for the benefit of science museum professionals. [3]

The Exploratorium, under a five year dissemination program, sponsored by Kellog Foundation, invited 125 museum professional from all over the world during 1980s as interns for two to five weeks to enable them to study Exploratorium exhibits in detail. The present author had visited Exploratorium for four weeks in August 1982 under the same program. [4]

2. An aerial view of The Place of Fine Arts, San Francisco.

3. The author in front of the rotunda of The Place of Fine Arts in August 1982

4. Inner view of the Exploratorium

First ever physics playground exhibits created at the Exploratorium

That is not the end of the story however and the epilogue to this wonderful journey of Frank Oppenheimer was recently unearthed by the present author in the form of a document which reveals another glorious creation of his. Under his guidance the physics playground exhibits were first developed in the Exploratorium in San Francisco in 1977. The efforts started yielding fruits when in 1977, the Exploratorium, had used a grant of USD 5,500 from Association for Science -Technology Centres (ASTC), Washington DC for developing ideas, designs and full scale prototype exhibits for a physics playground. Oppenheimer took joy in advising and sometimes helping with prototyping.

Post build-up, a detailed project completion report titled 'Planning a Physics Playground', dated 30 September 1977, was submitted to the ASTC by Charles Glorioso (Head, Electronics Development and Maintenance) and Peter Richards (Exhibit Design and Fabrication) of the Exploratorium. [5] With that a brief report announcing the achievement, titled "Exploratorium develops successful prototypes for playground equipment demonstrating physics", was published in the Newsletter of the ASTC in January 1978. [6]

Many of the interactive exhibits created by the Exploratorium for indoor or outdoor displays have been recreated by science museums and science centres all over the world for their Science Parks. Let us discuss here about eleven such exhibits in detail.

Sympathetic Swings

A prototype of this exhibit, called a Coupled Pendulum, was created by the Exploratorium in 1977. [5] It was planned for a Physics Playground, but was not installed permanently.

The exhibit consists of two swings supported from a common bar, which is further supported from the swing set frame. A visitor sits on one of the swings and asks his/her friend to sit on the other. He/she then starts swinging with a gentle push on the ground and then keeps his/her feet off the ground. The second visitor should always keep his/her feet off the ground. It is observed that the first visitor's energy begins to be coupled to the other swing through the intermediate bar. As the energy is transferred, the first person swings through smaller and smaller amplitudes and finally stops. At the same time, the second person's amplitude is steadily increasing. Thus energy will continue to transfer back and forth between the two swings for some time. Finally both the swings come to a halt.

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5. Coupled Pendulum of the Exploratorium

In the coupled swing system, each swing has two periods of oscillation, one due to the length from the seat to the intermediate bar and the other due to the length from the seat to the top of the swing set. If one watches the two swings from a distance he/she can understand the change of phase relationship between the swings. The swing which is accepting energy always lags in phase behind the source. Further, if both swings start together, either in phase or completely out of phase, no transfer of energy will take place between them. For all other phase relations there will be energy transfer.

In India the exhibit was named as a Sympathetic Swing (side by side) and has been installed in 40 out of 40 science parks. [7] The other version of the exhibit developed in India is called Sympathetic Swing (face to face), which is governed by the same principle as explained above. Coupled Swing exhibit of the second types is also displayed in Clore Garden of Science, Israel.

6. Sympathetic Swing (side by side) at Manipur Science Centre, Imphal, India

7. Sympathetic Swing (face to face) at Regional Science Centre, Bhubaneswar

Compound Pendulum

The prototype of the Compound Pendulum exhibit was created in the Exploratorium in 1977. [5] The exhibit in its original form was, however, never displayed for visitors in the Exploratorium. Subsequently, two other indoor exhibits, namely, Harmonograph [8] and Relative Motion [9], whose working principle is similar to a compound pendulum, were developed by Exploratorium. In India, the Relative Motion pendulum was installed in 18 science parks.

8. Compound Pendulum of the Exploratorium

The swing of the Compound Pendulum exhibit is in the form of a cage with a platform for a visitor to stand on. The cage is hung from the swing frame by two mutually perpendicular pivots, which are located at different heights from the cage floor and as a result the cage has different periods of oscillation along its two axes. When the swing or cage is set into motion by its rider by a gentle push, the platform travels through straight line, elliptical, circular, elliptical, and again a straight line path.

In the Relative Motion exhibit developed by Exploratorium and also by National Council of Science Museums in India, there are two swings – a rod pendulum and a platform. They move in directions perpendicular to each other. The visitor has to swing the central rod pendulum gently. Its pointed end traces a straight line. He/she then swings the platform and

9. Dr Frank Oppenheimer swinging from a Compound Pendulum in Exploratorium

10. Relative Motion pendulum at Kapilas Science Park, Dhenkanal, India

observes that the pointed end traces elliptical paths. The elliptical paths are generated by the resultant effect of two simple harmonic motions in perpendicular direction. [10]

A Swing is a Pendulum

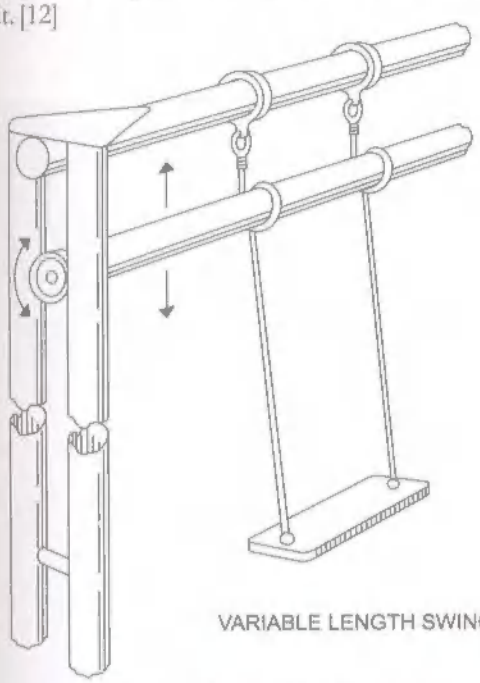
A playground swing is basically a pendulum, where the seat alone (or with a person in it) acts as the bob. The natural frequency of the swing depends on its length from the swing set bar and remains the same even if there is a change of mass due to change of the rider, a child or an adult. However to be more precise, the actual length of the swing is the distance from the top of the swing bar from where it is hanging to the centre of mass of the rider. The longer is the swing the lower is its frequency of oscillation.

Based on this property of a swing the Exploratorium in 1977 had designed a Variable Length Swing. [5] The swing was hanged by chains from a 20 feet high swing frame. It allowed one person to ride while a second person changed the effective length of the chain supporting the swing. There was a horizontal steel pipe between the frame cross bar and the swing seat which could be winched up and down by the second person to vary the effective length of the pendulum. Thus the frequency of oscillation of the swing could also be varied.

In 1975, Isamu Noguchi, a Japanese-American landscape architect, had created several designs of playground equipment for developing a Playscape in the Piedmont Park in Atlanta. The Playscape was completed in 1976, under the aegis of the High Museum of Art and a grant from the National Endowment for the Arts. From a close examination of the drawing of swings and the actual swing set installed in the park it now transpires that Noguchi's design had a solution for setting up swings of variable lengths. This was certainly simpler than the Exploratorium's design as explained above. [11].

Nehru Science Centre, Mumbai while creating science park exhibits in 1978, knowingly or unknowingly, used a design similar to that of Noguchi. When swings of two different lengths are occupied by visitors and set in to

motion, it is clearly observed that the longer swing is slower than the shorter swing and vice-versa. Out of 40 science park set up so far in India, 39 are having this exhibit. [12]



11. Design for variable length pendulum exhibit of Exploratorium

12. Swing set of Playscape at Piedmont Park in Atlanta

13. A Swing is a Pendulum exhibit at Nehru Science Centre, Mumbai

Slide Race

The Slide Race exhibit prototyped by the Expolratorium for Physics Playground in 1977 consisted of two pipe slides – one straight and other one a section of an epicycle. They were 40 feet (12.19 m) long and 14 feet (4.26 m)high. When two persons started sliding from the top simultaneously, the rider on epicycloid slide reached to bottom first, while the rider on straight slide was still 8 feet (2.43 m) up the slide. [5]

An epicycle is the curve traced by a point on a circle which rolls on the outside of a circular base surface. A cycloid is a curve generated by a point on the circumference of the circle as the circle rolls along a straight line without slipping. Although the shortest distance between two points is a straight line, the fastest path of descent is a brachistochrone curve. An epicycle or a cycloid path is a brachistochrone curve. If a body starts moving from rest along the curve without friction under constant gravity, it will reach the end point in the shortest time.

The NCSM in 1978 did similar experiment in their outdoor exhibit called Minimum Time Path, but used 8 inch diameter solid wooden balls. There are three rod slides – a straight slide, a circular path slide and a cycloid path slide. A visitor takes two balls on the top of any two paths and releases them at the same time. He/she observes that one ball comes down faster than the other. He/she then repeats this with another pair of paths. The visitor observes that in all cases the ball rolls down faster along a particular path. This particular path is the cycloid path. [13]

This exhibit has been installed in 22 science parks in India, but not in the science parks of any other country.

14. The pipe slides of the Slide Race exhibit of Exploratorium

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15. Participation in Slide Race exhibit of Exploratorium

16. Minimum Time Path exhibit at Kapilas Science Park, Dhenkanal, India

Downhill Race

Exploratorium's Downhill Race exhibit [14] has four different types of wheels which the visitors can roll down a smooth gentle slope. The wheels are (i) a ring, (ii) a uniform disc, (iii) an edge-weighted disc and (iv) a centre-weighted disc. The visitor has to choose any two wheels, hold them at the top of the ramp, and let them roll down simultaneously. When the race is between a uniform disc and a ring, the disc wins. When the visitor sets the race between a centre-weighted wheel and edge-weighted wheel, the wheel with heavy hub wins. It, therefore, experimentally established that the rate of angular acceleration of a rolling object depends not only on its mass, but on how that mass is distributed.

This exhibit has been recreated for science parks in India, Israel and some other countries. In India it is named as 'Win the Race.' The exhibit has only two wheels of equal weights, but one has small weights fixed at the hub while the other has same number of weights fixed near the rim. The result is same – the centre-weighed wheel always wins the race. It has, however, been noticed that some visitors do not care to read the instruction (label) and try to force the wheels to race differently.

17. Downhill Race exhibit of the Exploratorium

18. Win the Race exhibit at Science City, Kolkata

Resonant Pendulum

The challenge is to set the heavy bob of a pendulum into oscillation by applying a gentle force with the help of a small magnet tied to a string. The visitor has to toss the magnet on the bob so that it sticks to the iron collar wrapped on the bob. He/she then has to pull the string very gently to start swing of the weight. If he/she pulls too hard, the magnet gets detached from the bob. He/she, therefore, needs to give a small tug to the string every time the weight starts moving towards him/her and loosen his/her grip as weight swings away.

Thus by exerting very small force at just right time, he/she can make a massive pendulum bob swing back and forth with large amplitude. Like all other pendulums, this heavy bob pendulum too has a natural frequency of oscillation. When the frequency of pulls on the pendulum equals to its natural frequency, resonance occurs and as a result amplitude of oscillation increases. [15]

The Resonant Pendulum of Exploratorium was an indoor exhibit. It was subsequently installed in many Science Parks in India and also in Clore Garden of Science in Israel with some modifications.

19. Resonant Pendulum Exhibit in Exploratorium

20. Swing a Quintal Exhibit at Kapilas Science Park, India

Focused Sound

The concept of developing a pair of 'Sound Mirrors' for conversation of two persons in a whisper, separated by a distance of 50 feet (15.24 m) on a playground, was presented by Exploratorium in a report titled "Planning a Physics Playground" submitted to ASTC in 1977.[5]

It was initially planned to use two 8 foot (2.43 m) diameter parabolic microwave antennas as the sound mirrors. The actual exhibit was created a few years later by using two large plaster mirrors of parabolic surfaces, facing each other approximately 50 feet (15.24 m) apart in the exhibition hall of the Exploratorium. [16]

A visitor is asked to face a sound mirror with his/her ear close to the central ring placed at the focus of the parabolic reflector. Another visitor is asked to go to the other sound mirror and put his/her mouth close to its central ring. Thus when one visitor talks or whispers, the other can easily listen to that.

Sound originating from one focus of the parabolic reflector gets reflected by its surface and travels in parallel lines to the other reflector. There the sound is converged to the focus of the reflector.

21. Sound Mirror or Focused Sound in Exploratorium

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In India the same exhibit is called a 'Whispering Garden' whose dishes are made out of fibre glass. [17] As many as 37 Science Parks set up by the National Council of Science Museums in India between 1984 and 2014 have this exhibit on display. Being a very effective exhibit Sound Mirrors have been installed almost with the same design in many science parks in the world, such as in St. Louis Science Centre, New York Hall of Science, Singapore Science Centre, Technopolis in Brussels, Science Park Kiryat Tivon, Israel, etc.

22. Whispering Garden in Sikkim Science Centre, Gangtok, India

23. Whispering Dishes in St. Louis Science Center

24. Whispering Dishes in New York Hall of Science

25. Whispering Dishes in Technopolis, Brussels

26. Whispering Dish in Kinetic Garden of Singapore Science Centre

27. Whisper Catchers at the Science Park, Kiryat Tivon, Israel

Echo Tube

Exploratorium's Echo Tube is an indoor exhibit. It is a 100 ft (30.4 m) long tube sloped up from the floor level to the ceiling of the Exploratorium hall. The echo tube is made by joining five 20 ft (6 m) long tubes of 18 inch (45 cm) inner diameter. [18]

When a visitor brings his/her mouth near the lower end of the tube and says Hello, he hears a distinct echo. Sound wave travels through the tube at a velocity of 330 mt per second and come back reflected from the other end. The visitor can hear an echo if the reflected sound returns to his ears at least one-tenth of a second after the original sound.

This exhibit has been installed in as many as 37 Science Parks in India between 1984 and 2014. [19]

28. Echo Tube at Exploratorium

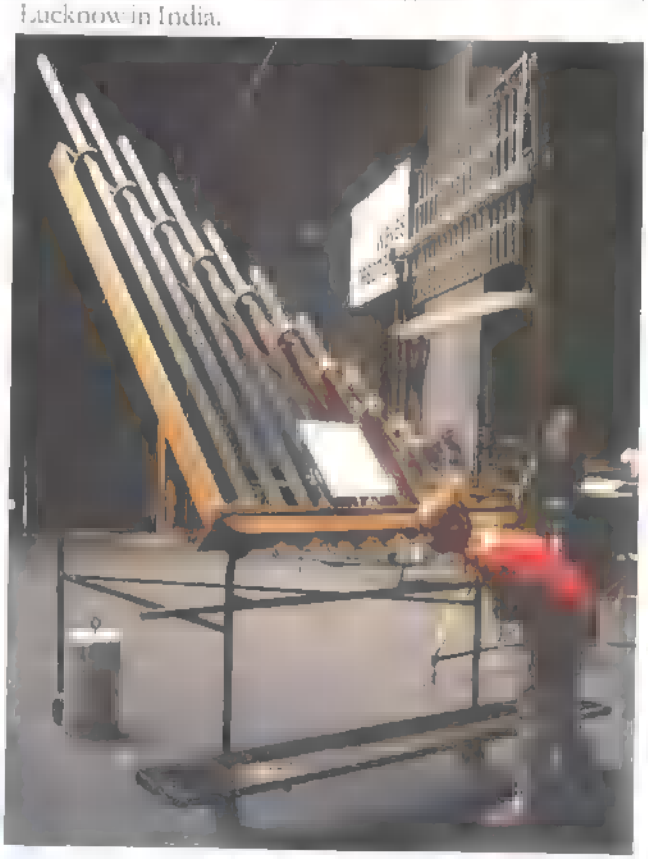
29. Echo Tube at Regional Science Centre, Bhubaneswar

Pipes of Pan

The indoor exhibit, Pipes of Pan of the Exploratorium is a simplified version of the Pan Flute, a musical instrument, considered to be the oldest wind instrument in the world. The exhibit consists of ten glass pipes, each of 3.81 cm diameter and their lengths ranged from 30.5 cm to 305 cm with an increment of 30.5 cm. [20]

A visitor when brings his/her one ear very near to the lower end of any of the pipes, he/she can hear a distinct note or musical sound. When he/she goes to another pipe, a different note is heard. Longer the pipe, lower the tone or the frequency of the note. Such musical sound or note is created due to resonance of a particular sound whose frequency is determined by the length and inner diameter of the glass tube. However, when the visitor keeps his/her ear little away from the lower mouth of a pipe, he will listen to the ambient noise. The result will be same when experimented with other tubes.

This exhibit was subsequently recreated by Clore Garden of Science, Rehovot, and Science Park, Kiryat Tivon, both in Israel, and Regional Science City, Lucknow in India.



30. Pipes of Pan in Exploratorium

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31. Pan Flute at the Science Park, Kiryat Tivon, Israel

Momentum Machine

The Momentum Machine demonstrates the principle of conservation of angular momentum. The angular momentum depends on the mass of an object, its velocity and how far the mass is from its axis of rotation.

In Exploratorium's Momentum Machine exhibit, the visitor stands on a circular platform that can freely rotate. With a slight push, the visitor can twirl around. When he/she brings body parts closer to the axis of rotation he/she spins faster and the vice-versa. [21]

This exhibit has been replicated worldwide as an interesting and effective indoor exhibit. In India an exhibit named 'Turn Faster' has been developed to demonstrate the same principle, but in a different way. Here the visitor sits on a revolving chair and pushes two weights on either side of his/her body to full arm lengths and hold them. He/she then asks his/her friend to give a turn. While rotating he/she brings both the weights close to his/her body and spins faster. When he/she pushes both the weights away he/she turns slower. [22]

32. Momentum Machine exhibit at Pertosains, Kuala Lumpur in Malaysia

33. Turn Faster exhibit in Manipur Science Centre, Imphal, India

Impossible Triangle

The Impossible Triangle was created first by Swedish artist Oscar Reutersvard in 1934. British psychiatrist Lionel Penrose and his mathematician son Roger Penrose too conceptualized and developed this form in 1950s. It is therefore called the Penrose Triangle or the Penrose Tribar.

The Impossible Triangle is a large wooden structure of three long bars of square cross sections. The bars meet pair-wise at right angles. However, when viewed from a particular point from a distance the entire structure appears to be an equilateral triangle. When visitors come close to the structure, or change viewing point, they discover that their perception was false. [23]

In India the Impossible Triangle exhibit was installed in two science parks only. The exhibit is however installed as an optical illusion sculpture in the Claisebrook Roundabout in East Perth, Western Australia, in Expi Hands-on Science Center, Gotschuchen, Austria and Singapore Science Centre.

There are several other indoor exhibits of Exploratorium, concept of which have been used for developing outdoor science par exhibits in Indian and many other countries. Some of the titles are Reverse Masks, Harmonograph, Optic Tree, Trapizoidal Window, Depth Spinners, Bird in the Cage, Circular Scales, Bicycle Wheel Gyro, Non-round Rollers, Square Wheels, etc.

34a. Impossible Triangle exhibit of Exploratorium (view 1)

34b. Impossible Triangle exhibit of Exploratorium (view 2)

35. Impossible Triangle sculpture, at EXPI Hands-on Science Center, Gotschuchen, Austria.

36. Impossible Triangle exhibit at Kinetic Garden, Singapore Science Centre

Conclusion

Imagine if the actual inventor of such fantastic Exploratorium had kept to himself his work. It would have taken perhaps decades longer to achieve something this beneficial and knowledgeable. Hence, his ideal to share knowledge is definitely commendable. Knowledge after all is that peculiar thing which increases as we share and so believing in this fact, Dr. Oppenheimer had opened all the windows for everyone to peek in and have such exhibits made in their countries. The true usage of any invention lies in the fact that it is beneficial for all and that is the right way to evolve together to a better tomorrow.

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[23] Cookbook I, Recipe No.57. © Exploratorium (1975).

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